State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES

Scott McCallum, Governor
Darrell Bazzell, Secretary
Scott A. Humrickhouse, Regional Director

Sandhill Wildlife Area
Sandhill Outdoor Skills Center
Box 156
Babcock, Wisconsin 54413
Telephone 715-884-6333
FAX 715-884-6330

14 September, 2001

Subject: Sandhill Outdoor Skills Center High School Independent Studies Annual Report

Greetings!

This is the sixth annual report summarizing the data collected by high school student participants during the 2000-2001 school year. Twenty students from 8 school districts participated in the previous year's program.

Juniors and seniors are selected based on academic ability and performance. All students attend a training session before joining an inter-school district field team. Field teams are present and collecting data Mondays through Fridays, with each student reporting to Sandhill on their assigned dates throughout the study period. Following the field season, each field team reassembles at Sandhill to analyze the data they collected during their respective field seasons. Many students prepare reports as part of credit for courses in biological and environmental topics back at their respective schools.

The enclosed report summarizes the data these students collected during the 2000-01 field season in both the Porcupine Ecology and Wolf-Deer studies. While written by Skills Center staff, the quantity and quality of these students' data are impressive.

The Skills Center wishes to acknowledge the support of both **Whitetails Unlimited, Inc.** and **Consolidated Papers Foundation, Inc.** for their financial support of these very worthwhile ventures.

Sincerely,

Dick Thiel *Laura Huber*

Dick Thiel, Coordinator
Sandhill Outdoor Skills Center

Laura Huber, Assistant

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Porcupine Ecology Study
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Sandhill Outdoor Skills Center
Sandhill Wildlife Area, Department of Natural Resources
Box 156
Babcock, WI 54413

Participants:

Student	**School**	**City**	**Teacher**
Lori Bohm*	Marshfield Senior High	Marshfield	Mr. Christianson
Angie Bowden*	Lincoln HS	Wisconsin Rapids	Mr. Stankowski
Richie Erickson*	Tomah HS	Tomah	Mr. Spiers
Kevin Mahar*	DC Everest HS	Schofield	Mr. Miller
Nick Thomas*	DC Everest HS	Schofield	Mr. Miller
Jeremy Traska*	DC Everest HS	Schofield	Mr. Miller
Emilie Wyman*	Marshfield Senior High	Marshfield	Mr. Christianson

*assisted with data compilation/analyses

Introduction

Porcupines (*Erithizon dorsatum*) are endemic to forested regions of Wisconsin (Jackson 1961). This species is well known for the damage it causes to forest trees. Foresters and woods-persons alike have killed porcupines - on sight - for generations (Jackson 1961,Krefting et al. 1962). Aside from humans, fishers (*Martes pennanti*) are the porcupine's only significant predator. Porcupines began colonizing central Wisconsin in the mid-1970's (Thiel unpubl.). The relatively recent reestablishment of porcupines to this region provides an opportunity to witness how the porcupine population has responded to this previously unutilized forest resource, and to determine what impacts porcupines have on forest trees.

Study Area: The present study is restricted to the southern half of Sandhill Wildlife Area located in southwestern Wood County, Wisconsin. It is owned and managed by the Wisconsin Department of Natural Resources, Bureau of Wildlife Management. This 9,150-acre wildlife area is surrounded by a nine-foot tall, deer-proof fence. Half of the area consists of wetland complexes. Upland forest and small grassland openings, the largest of which is 260 acres, occupy the remainder. Porcupines have been present on Sandhill since about 1978 (Thiel unpubl). Fisher tracks were observed in Sandhill Wildlife Area this winter.

The objective of the present study is to determine the demographics (age, sex and population size) and spatial organization of the porcupine population within Sandhill Wildlife Area.

We hypothesize:
1). the relative age of porcupines can be determined by tooth wear and weight,
2). winter den availability is not presently a limiting factor, and
3). the porcupine population on Sandhill Wildlife Area is stable, but below carrying capacity.

Methods

Population Parameters and Demographics: Between November and April each year, porcupines occupy wintering dens (Roze 1989). Searches were initiated by Sandhill personnel in November at den sites where porcupines were observed in previous winters. Additional den sites were found by systematically searching each woodlot in the southeastern quarter of Sandhill, looking for evidence of dens or porcupine trails. Den sites were considered “active” if a porcupine was seen, or if porcupine tracks or other fresh sign was present at the den. Den sites were considered “old” if there was no fresh sign present, but evidence of use in past years was found. “Potential” den sites were characterized by a hollow tree, log, hummock, or rock crevice that had potential for use, but no sign indicating use by porcupines. The locations of each den was plotted on study maps along with its “active,” “old,” or “potential” classification. The acreage of each surveyed woodlot was determined by dot-grid analysis from aerial photographs. At the end of the field season, den densities were calculated by dividing the number of dens found by the total area of woodlots surveyed:

Den density (D_{den}) in the surveyed area:

$$\mathbf{D_{den} = Cumulative\ n_{den} \div Area_{Total\ surveyed}}$$

Minimum porcupine density was calculated for the study area by dividing the number of porcupines found by the total area of woodlots surveyed:

$$\mathbf{Min\ D_{porcupine} = n_{captured} \div Area_{Total\ surveyed}}$$

Porcupine density was recalculated for the study area to include animals known to exist but never captured. The number of known, uncaptured animals were added to the number of captured animals and the sum divided by the total survey area.

$$\mathbf{D_{porcupine} = (n_{captured} + n_{known,\ not\ captured}) \div Area_{Total\ surveyed}}$$

Porcupines captured outside of the surveyed study area were excluded from this calculation.

Porcupines were handled after injecting them with Telazol (Hale et al. 1994). Porcupines were captured by hand injecting them in dens, placing traps at den entrances, or surrounding the tree in which a porcupine was roosting with one-m-tall chicken wire, along which a trap was situated. All captured porcupines were weighed, sexed, ear-tagged, and color coded with spray paint to aid in identification from a distance. A Passive Integrated Transponder (PIT) tag (AVID Friendchip, 14mm) was injected between the shoulder blades of each porcupine captured.

Turn-over Rate: Turn-over is the rate at which animals are replaced by other individuals. Turn-over is a function of emigration/immigration, and birth/death. No barriers exist impeding movement of porcupines in our study area. Birth and death rates are difficult to assess, based on techniques used in the present study, but turn-over can be assessed by analyzing the relative recapture frequencies of porcupines ear-tagged in previous years. Turn-over was calculated by the following formula:

$$\mathbf{Turn\text{-}over = 1 - (n_{capyear+1} \div n_{capyear}) * 100}$$

Where: n = number of porcupines
capyear = capture year
capyear+1 = the year following capture

Ear Tag Retention: Ear tag losses are known to have occurred within given field seasons and between seasons. Ear tag retention rates were calculated as follows:

$$\mathbf{R = (n_1 + n_2 \ldots + n_w) \div (n_0 + n_1 \ldots + n_{w-1})}$$

Where: R = estimated probability of ear tag retention
n_0 = number of animals tagged in original cohort
$n_{\#}$ = number of eartags remaining in animals x# years after original tagging
n_w = number of eartags remaining in animals at last year of study

Aging: Porcupine premolar/molar rows were examined and tooth replacement and wear were recorded. The sequence of tooth replacement allows for accurate aging of juvenile (age <1 year), yearling (age 1-2 year) and adult (≥ 2 years) (Kochersberger 1950, Roze 1989). Adult tooth wear was subjectively ranked as "no wear", "light", "moderate", or "heavy" based upon examination of porcupine skull specimens at the University of Wisconsin Zoological Museum.

Weight data were analyzed for potential as an age estimator. Data collected from 1998-2001 were combined and then separated by sex and age class (female: juvenile, yearling, adult; male: juvenile, yearling, adult) based on tooth replacement. The range and mean were calculated for each data set. Preliminary weight limits for each age class were determined.

Louse Infestation: Each porcupine was examined for louse (*Trichodectes setosus*) infestation in four body areas (ventral: thoracic and inguinal; dorsal: nape and rump). Infestation was rated subjectively as: 0 - no lice present, 1 - light infestation, and 2 - heavy infestation. A lice index for two-month periods was calculated by:

$$\textbf{Lice Index} = \Sigma\,[\,\Sigma\,\textbf{(lice infestation at sites 1,2,3,4)}_{\textbf{porkies 1 . . n}}\,]_{\textbf{n porkies}} \div \mathbf{n_{porkies}} \div \textbf{4 body sites}$$

Weight Change: Winter weight loss was calculated for the field season using individuals captured and recaptured between November and April of the field season. Average daily weight loss (W_{DL}) was calculated using the weight at capture and the weight at recapture.

$$\mathbf{W_{DL}} = \textbf{(Weight Change}_{\textbf{initial capture – recapture}}\textbf{)} \div \textbf{No. Days Between Captures}$$

W_{DL} was compared with the corresponding Winter Severity Index (WSI) for the Central Forest region, Zone L (Sandhill DNR unpubl.). WSI is a relative measure using snow depth and temperature data for the period 1 December – 31 March.

"Summer" weight gain was calculated using individuals captured and recaptured between February and December of the calendar year. Average daily weight gain (W_{DG}) was calculated using the weight at capture and the weight at recapture.

$$\mathbf{W_{DG}} = \textbf{(Weight Change}_{\textbf{fall wt – spring wt}}\textbf{)} \div \textbf{No. Days Between Captures}$$

Mortalities: Porcupines found dead within the study area were necropsied by the DNR pathology section in Madison if found in good condition.

Results

Population Parameters and Demographics: A total of 520 acres (2.10 km^2) of upland habitat was surveyed in southeast Sandhill Thirty-eight active, old, and potential dens were located in the surveyed area (Table 1). Most of these dens were hollow tree dens, one was a rock den, and two were located underground at the base of uprooted trees. Density of active dens was 7.62 dens/km^2, while the density of all active, old, and potential dens combined was 18.09 dens/km^2 (Table 1).

Table 1. Winter porcupine den density in SE Sandhill Wildlife Area, WI, 1997-98 and 2000-01.

Den Type	Number found		Dens/100 acres		Dens/km^2	
	1997-98	2000-01	1997-98	2000-01	1997-98	2000-01
Active	11	16	0.9	3.1	2.2	7.6
Old or Active	17	21	1.8	4.0	4.5	10.0
Potential, Old, or Active	24	38	3.1	7.3	7.6	18.1

Assuming one porcupine per active den, 16 porcupines were present in the surveyed area. Based on that assumption, porcupine density in the southeastern focus area was 3.1 porcupines/100 acres (7.6 porcupines/km^2).

A total of ten different porcupines were captured in the entire study area's 1947 acres of uplands. Two of those individuals, both adult females, were originally captured in the 1996-97 field season. Minimum porcupine density was 0.5 porcupines/100 acres (1.3 porcupines/km^2). When porcupine density was recalculated to include animals known, but never captured (n = 14), density increased to 1.2 porcupines/100 acres (3.0 porcupines/km^2).

Seven of the ten captured porcupines were found in the southeastern focus area, as were five other animals that were never captured. Minimum porcupine density within the southeastern focus area was 1.35 porcupines/100 acres (3.3 porcupines/km^2). Porcupine density within this same area was calculated to be 2.31 porcupines/ 100 acres (5.7 porcupines/km^2) when known, but uncaptured animals were accounted for.

Turn-over Rate: Five years of capture data were analyzed to calculate a turn-over rate of 75 percent.

Ear Tag Retention: Sixty-four ear tags were placed on porcupines in the study area since 1996. Twenty-one of those animals were recaptured. Tag retention rates were calculated using those 21 recaptured individuals (Table 2).

Table 2. Minimum ear tag retention rates for porcupines in Sandhill Wildlife Area, WI, 1997-2001.

Length of Retention	# Observed	Retention Rate
< 1 yr	1	4.8%
1+ yr	15	71.4%
2+ yr	4	19%
3+ yr	1	4.8%
4+ yr	0	0%

Age-Sex Ratios: Tooth replacement and wear were used to determine age-classes among captured porcupines. Five adults, two yearlings, and two juvenile porcupines captured in 2000-01 were examined and aged (Table 3). The female/male ratio for adult captures was 4.8 (Table 4). The female/male ratio for all captures was 1.5 (Table 5).

Table 3. Age-sex distribution of porcupines captured in Sandhill Wildlife Area, WI, 2000-01.

	Adult Female	Adult Male	Yearling Female	Yearling Male	Juvenile Female	Juvenile Male	Total
n Captured	5	1	1	1	0	2	10
% of Total Capture	50%	10%	10%	10%	0%	20%	100%

Table 4. Sex ratio of adult captured porcupines in Sandhill Wildlife Area, WI, 1996-2001.

	% Female	% Male	? /? ratio
1996-97*	88	12	7.33
1997-98	56	44	1.27
1998-99	62	38	1.63
1999-2000	77	23	3.35
2000-01	83	17	4.8
Overall, 1996-2001	70	30	2.29

* two individuals were excluded because gender was unknown.

Table 5. Sex ratio of *all* captured porcupines in Sandhill Wildlife Area, WI, 1996-2001.

	% Female	% Male	? /? ratio
1996-97*	82	18	4.5
1997-98	57	43	1.33
1998-99	55	45	1.22
1999-2000	59	41	1.44
2000-01	60	40	1.5
Overall, 1996-2001	51	49	1.03

* two individuals were excluded because gender was unknown.

Weight data for 1998-99, 1999-2000, and 2000-01 field seasons were combined by age class for analysis. The mean weight for adults was 15lb (6.8 kg), while the mean for yearlings and juveniles was 9.4 lb (4.3 kg) and 5.6 lb (2.5 kg) respectively (Table 6).

Table 6. Weight ranges and averages by age and sex for porcupines captured in Sandhill Wildlife Area, WI, 1998-2001.

		Juvenile	Yearling	Adult
Male	**High**	7.0 lb (3.2 kg)	12.0 lb (5.5 kg)	20.3 lb (9.2 kg)
	Mean	5.7 lb (2.6 kg)	10.1 lb (4.6 kg)	15.2 lb (6.9 kg)
	Low	4.0 lb (1.8 kg)	8.0 lb (3.6 kg)	12.0 lb (5.5 kg)
Female	**High**	5.5 lb (2.5 kg)	10.5 lb (4.8 kg)	17.0 lb (7.7 kg)
	Mean	5.3 lb (2.4 kg)	8.7 lb (3.9 kg)	14.9 lb (6.8 kg)
	Low	5.0 lb (2.3 kg)	6.5 lb (2.9 kg)	11.0 lb (5.0 kg)
Overall Mean		5.6 lb (2.5 kg)	9.4 lb (4.3 kg)	15.0 lb (6.8 kg)

Age-weight analysis was used to determine probable age class ratios of porcupines caught in 1996-97 and 1997-98. Adults were defined as animals weighing >11lbs, yearlings as 6-11lbs, and juveniles as <6 lbs. Based on age-weights, adults comprised from 62 to 77 percent of the population; yearlings comprised 10 to 29 percent; juveniles from 0 to 28 percent (Table 7).

Weight Fluctuation: No porcupines were captured and recaptured within the timeframe for calculating winter weight loss or summer weight gain during this study period.

Table 7. Age ratios of captured porcupines in Sandhill Wildlife Area, 1996 - 2001.

		Juvenile	Yearling	Adult
1996-97[1]	**n**	**1**	**2**	**10**
	%	**8**	**15**	**77**
1997-98[1]	**n**	**0**	**6**	**15**
	%	**0**	**29**	**71**
1998-99	**n**	**2**	**5**	**13**
	%	**10**	**25**	**65**
1999-2000	**n**	**6**	**2**	**13**
	%	**28**	**10**	**62**
2000-01	**n**	**2**	**2**	**6**
	%	**20**	**20**	**60**

[1] based on age-weight analysis

Louse Infestation: Heaviest louse infestation was observed from January through April. November and December had the lightest louse loading (Table 8). Juvenile and yearling porcupines exhibited a higher rate of infestation than their adult counterparts.

Table 8. Porcupine lice loading index by time period in Sandhill Wildlife Area, WI, 2000-01.

Time Period	No. Porcupines Sampled	Lice Index
November/December	**3**	**0.92**
January/February	**4**	**1.25**
March/April	**1**	**1.25**

Mortalities: Three marked study animals were found dead during the study period. Two mortalities occurred within Sandhill. In April 2001, an adult male was found dead and considerably decomposed. Cause of death is unknown, but the animal's tail was severed and removed from the area. A juvenile male was found dead and highly decomposed outside of a den entrance in May 2001. In late April, a marked yearling male porcupine was found dead on Hwy X (outside of Sandhill boundary fence); cause of death was car kill. None of these animals were sent for necropsy because of their state of decomposition.

Discussion

Porcupines selected hollowed trees, rock outcroppings, and culverts as winter dens. The highest den density was located on North Bluff in 2 escarpments. Rock outcroppings were preferred over hollow tree dens in other studies (Roze 1989, Krefting et al. 1962).

In the 1997-98 and 2000-01 field seasons, the same section of Sandhill Wildlife Area was surveyed. In the 1997 field season, 255 more acres were surveyed than in the 2000 field season. Regardless, 14 more active, old, and potential dens were found in 2000. Snow conditions between these two field seasons were markedly different. In 2000, we had considerably more snow which enabled us to locate porcupine trails more effectively than in the "sketchy" snow conditions of 1997.

Some dens within our study area were used by more than one individual. Den sharing was observed throughout the study area, including the southeastern surveyed portion. Painted quills shed near a den and captures of different animals from the same den were indicative of den "swapping."

To calculate the minumum porcupine density, we assumed one porcupine per active den. Our calculation of 3.3 porcupines/km^2 was based on sixteen active dens in the surveyed area. The propensity of den-swapping and inadequate trapping effort at active den sites leads to an inherent error in the assumption of one porcupine per active den. A "corrected" porcupine density of 5.7 porcupines/km^2 accounts for animals seen in the study area, but left uncaptured. Porcupine density is likely higher than these calculations. Winter porcupine density in the Hiawatha National Forest in Michigan's upper peninsula was found to be 3.5 porcupines/km^2 without fishers present (Roze 1989). In the Ottawa National Forest in upper peninsula Michigan, porcupine density ranged from 11.8 porcupines/km^2 prior to fisher recolonization, to 0.8 - 2.8 porcupines/km^2 ten years following fisher recolonization (Roze 1989).

Porcupine density within Sandhill has probably not reached carrying capacity. Five "old" dens were found within the surveyed area. These dens were used in past years, and were still useable during this study period. Seventeen "potential" dens were found within the surveyed area, which could likely be used as winter den sites. This indicates that winter den sites are not a limiting factor for porcupines in the surveyed area. Long-term population data for porcupines on Sandhill is not available. Limiting factors acting on porcupines within Sandhill are unclear, but do not appear to be related to the availability of den sites.

Turn-over in a population is caused by movements of individuals into and out of the study area, and by variations in birth and death rates. In January 2000, movement of porcupines in and out of the study area was documented for the first time. Movement out of the study area was documented again in 2001, when a yearling male porcupine was found dead on a road outside of Sandhill.
Reliable identification of individuals is imperative to calculate turn-over rates accurately. Ear tag loss has been documented within study years and between years. Paint remnants, ear scars, and nipple counts were used with limited confidence to identify animals suspected of losing an ear tag. "Mistaken identity" may contribute to the calculated 75% turn-over rate. We hope that PIT tags will eliminate the problems caused by lost ear tags and allow us to calculate turn-over rates and other population statistics more accurately. PIT tags allowed us to identify three mortalities this study period that otherwise would have gone unidentified.

Inequalities in recapture probability may also contribute to high turn-over rates. Since the beginning of the porcupine ecology research project, 50% of all females captured have been recaptured at least once.

During that same period, only 10% of all males captured have been recaptured. There are a number of possible explanations for this difference in recapture rates, including lower survival rate for males, increased mobility for males, different winter den preferences, or perhaps males learn to avoid traps earlier than females do. This difference in recapture rates will be a focus of this study in the future.

Porcupine tooth replacement patterns allowed us to immediately separate young animals into the juvenile or yearling age classes. Tooth wear may allow us to subdivide adults into more specific age classes, but more data is needed, preferably a continual wear record for each individual we study. Tooth wear is currently used to age whitetail deer (*Odocoileus virginianus*) and other large herbivores. Tooth wear differs with diet and nutrition (Wilson et al. 1996), but this problem should be overcome by developing an aging technique with porcupines local to Sandhill.

Body mass is a good indicator of age in medium and large-sized mammals because it changes so much during early development stages (Wilson et al. 1996). During the last two field seasons, a relatively clear weight division between juvenile, yearling, and adult porcupines existed. There is certainly a clear weight division between the age classes when males and females are considered separately. The weight definitions have changed slightly with increased sample sizes, but we are confident these changes will continue to be slight. The sample sizes for juvenile and yearling animals are very small. An additional two juveniles and an additional two yearling animals changed the mean weight for these age classes by 11% and 4% respectively. An additional 4 adults had no impact on the mean weight for that age class. A larger sample size is needed for both juvenile and yearling animals to attain a reliable data set.

In six prior studies outside Sandhill, female/male ratios have ranged from 1.08 to 1.91 for animals of all ages (Roze 1989). The observed sex ratio of 1.03 at Sandhill is nearer to a 1:1female:male situation than any study. It is the result of five years of study and captures of 61 individuals. Our sample size of 61 is second lowest of all of the studies (range: 54 - 214), and this may account for some of the difference.

Roze (1989) proposed that nursing offspring pick up lice directly from their mother or from her shed fur in the spring. Neither explanation fits our observation of highest infestation in March and April, about the time animals are leaving their winter dens. We hypothesize that transmission of lice is likely a direct result of den sharing or switching during the winter months, as porcupines are primarily solitary animals during the rest of the year. We do not, however, capture animals throughout the year to observe lice loading trends throughout the year.

We thank Consolidated Papers Foundation, Inc. for their support of the porcupine ecology study.

Literature Cited

Hale, M. B., S. J. Griesemer, and T. K. Fuller. 1994. Immobilization of porcupines with tiletamine hydrochloride and zolazapam hydrochloride (Telazol). Journ. Wildl. Dis. 30: 429-431.

Jackson, H.H. 1961. The mammals of Wisconsin. University of Wisconsin Press, Madison. 504 pp.

Kochersberger, R.C. 1950. A study to determine cranial and dental correlations with age and sex in the Canadian porcupine. Masters Thesis, Biology Dept. University of Buffalo, NY.

Krefting, L. W., J.H. Stoekeler, B. J. Bradle and W. D. Fitzwater. 1962. Porcupine-timber relationships in the lakes states. Journ. For. 60 :325-330

Roze, U. 1989. The North American porcupine. Smithsonian Institution Press, WashingtonD.C. 261 pp.

Wilson, D.E., F.R. Cole, J.D. Nichols, R. Rudran, and M.S. Foster. 1996. Measuring and monitoring biological diversity – standard methods for mammals. Smithsonian Institution Press, Washington DC. 409 pp.

Deer - Wolf Ecology Studies
Sandhill Wildlife Area, 2000-01
Sandhill Outdoor Skills Center

Sandhill Wildlife Area, Department of Natural Resources
Box 156
Babcock, WI 54413

Participants:

Student	**School**	**City**	**Teacher**
Jenny Beckord*	Tomah	Tomah	Mr. Guerkink
Amanda Beyer	Waupaca	Waupaca	Mr. Welch
Claire Furlano*	Tomah	Tomah	Mr. Guerkink
Chris Kohl*	Ripon	Ripon	Mr. Bogdanske
Jordan Mancl*	Lincoln	Wisconsin Rapids	Mr. Engelein
Ben Preston*	Wonewoc-Center	Wonewoc	Mr. Cler
Kellie Riedl	DC Everest	Schofield	Mr. Miller
Aaron Slattery*	Lincoln	Wisconsin Rapids	Mr. Engelein
Candice Spinler*	Lincoln	Wisconsin Rapids	Mr. Engelein
Melissa Stowers	West Salem	West Salem	Ms. Thompson
Aistis Tumas*	Ripon	Ripon	Mr. Bogdanske
Jill Voelker*	Lincoln	Wisconsin Rapids	Mr. Engelein
Travis Wojtowicz*	West Salem	West Salem	Ms. Thompson

* assisted with data compilation/analysis

Introduction

Sandhill Wildlife Area in southwestern Wood County, Wisconsin, a 9,150 acre facility operated by the Wisconsin Department of Natural Resources, is entirely surrounded by a 9-foot tall, deer-proof fence. Studies on deer (*Odocoileus virginianus*) herd age-sex composition, harvest impacts, and deer census techniques have been conducted on Sandhill since 1962. Much of the previous work has focused on aspects of human harvesting of deer.

Humans hunt deer for sport in highly regulated seasons. Wolves are predators of white-tailed deer (Mech and Frenzel 1971, Kolonosky 1972, Thompson 1952). Some deer hunters express concern that wolf predation may affect their success in hunting white-tails (McRae 1994, Pryse 1997).

Wolves (*Canis lupus*) have been absent from the Sandhill region since circa 1900, but recolonized the area beginning in 1992 (Thiel 1993). An adult male wolf escaped into Sandhill in May 1995 and has resided there since (Boehm 1997, Thiel 2000).

Until recently, canid predation (limited to coyotes [*Canis latrans*]< 1995) on deer in Sandhill was not considered appreciable. Assessing the impacts of predation requires that, “the number of wolves in an area, the number of prey animals in the same area, and the rate at which the wolves remove the prey” be known (Kolenosky 1972). Such quantitative data is difficult to measure. Further, factors such as snow depth and competition at kill sites with scavengers (mainly coyotes and corvids) influence kill rates (Fuller 1991, Paquette 1992).

The purpose of this study is to:
(1) determine the spatial partitioning of bucks and does,
(2) calculate survivorship trends among deer, and
(3) ascertain the influence of both human harvest and wolf predation on deer.

Methods

Weather. Data were maintained on daily temperatures, snowfall, and snow depth by students and DNR personnel at Sandhill Headquarters. A Winter Severity Index (WSI) measures the relative impact of winter weather on deer herd condition. The formula for the Central Forest WSI is:

WSI = # days < 0°F +
#days with 6-11 inches of snow on ground+
2 X (# days with 12 – 17 inches of snow on ground) +
3 X (# days with < 17 inches of snow on ground)

Wildlife Populations. Annual coyote, beaver (*Castor canadensis*) and deer population statistics were gleaned from files maintained at Sandhill headquarters. Annual beaver colony counts provide the basis for long-term beaver population indices. Age-sex data are maintained on deer harvested by humans and deer dying natural deaths. Herd size and productivity are determined by irregular helicopter censuses and fall trail counts, and summer deer observations, respectively.

Wolf Study. Students entered the facility almost daily, Monday through Friday, working in teams of 1 to 4 people and walked, snowshoed, or drove along roads searching for wolf tracks. When tracks were encountered, students attempted to trail the wolves to locate prey remains. Students recorded information on distances traveled daily, and distances traveled on wolf trails.

Scats encountered on trails were teased apart to identify prey remains. Tracks adjacent to scats or the diameter of scats were used to distinguish between coyote and wolf droppings (Weaver and Fritts 1979). Kill-sites were inspected to determine the species, age and sex, and condition of prey at time of death. Vital materials such as jaws used in aging deer, were removed and given to DNR personnel for age analyses (Anon.n.d.). Samples of bone marrow, taken from the femur bone, were collected to determine health condition (Mech and DelGiudice 1985).

Deer Study. Deer were captured in a Grange Model box trap baited with hay. Captured deer were subdued by opening one trap door over which a net was suspended and pinning them to the ground. Radio transmitter collars were placed on selected deer while subdued. All deer captured were sexed and ear-tagged. Attempts were made to estimate age by inspecting wear on lower incisor teeth, and by assessing relative body size.

Deer were released at capture sites, and locations were obtained once weekly by determining direction of radio signals from pre-selected locations, recording bearings, and plotting triangulations on maps, as described by Mech (1983). Locations with large "errors of polygon" were rejected and not used in determining home range size. Deer locations were plotted on maps drawn from aerial photographs, and home ranges were determined by using the minimum area method (Mohr 1947 *in* Nelson 1981).

Impact of Wolf Predation. Age of predator-killed deer was compared to 2000 hunter-killed age statistics, and the age structure of non-harvested deer recovered in Sandhill between 1963 and 1994. Age stratification of the non-harvested deer cohort was assumed to represent herd age spread and was used to determine if humans and predators (wolves and coyotes) were selecting different age groups.

Utilization rates were determined by estimating the percent of each carcass that had been consumed by the wolf or coyotes, and returning to carcasses periodically to determine if each had been subsequently utilized. Consumption was calculated by determining the age and sex of deer when possible, and utilizing weight data on fall hunter-killed deer at Sandhill (Table 1) (DNR files), converting dressed weight to whole weight using the formula:

Whole Weight = 4.15 + 1.2487 x dressed weight

used by Kolenosky (1972). Daily consumption rates were calculated by taking this figure and multiplying it by the percent utilization of each carcass, and dividing by the number of days wolf trails were followed:

[3 (Whole Weight) x % utilization]) # days on wolf trails

Weights were expressed in kg.

Table 1. Mean dressed weights (kg) of Sandhill deer harvested in November 2000 (Sandhill DNR files).

Sex	Age						
	Fawn	**1**2	**2**2	**3**2	**4**2	**5**2	**6**2
Buck	24.6	40.4	53.5	61.7	73.4	79	-
Doe	23.5	34.4	41.4	45	51.5	-	-

The impact of wolf predation on the deer herd can be determined by calculating the number of deer preyed on by wolves using the following formula:

 # Deer Taken by Wolves Annually =

*3*Season **[kg/Wolf/Day x # Days x % Deer in scats x # wolves**
) 0 **Deer Wt (kg)**]

where season is divided by monthly periods, and the mean deer weight is 54 kg.

Scavenging of deer gut piles and unretrieved deer killed by hunters following the deer hunting season is another potential food source for wolves and coyotes. Hunters were asked to report the location of any dead deer they encountered while hunting. These were inspected by DNR staff immediately following the hunting season to gain an impression of the volume of food available to canids following the November hunt. Age and sex were determined, and weights were calculated for each dead deer. Students inspected these carcasses at irregular intervals, noting incidences of scavenging by species, and amount. Consumption rates were calculated in the same manner as discussed above.

Results

Weather Data:

Work was conducted on 28 days between 2 January and 22 March 2001. A low of -27°F was recorded on 25 December, and a high of 53°F was recorded on 20 March. Table 2 describes snowfall and mean depth, in inches, by month during winter 2000-01.

Table 2. Sandhill snowfall data, winter 2000-01.

Month	December	January	February	March
Total Snowfall:	**21.3**	**10.9**	**6.15**	**5.7**
0 **depth:**	**7.8**	**11**	**10.7**	**8.8**

Continuous snow cover extended over a 134-day period from 16 November 2000 through 27 March. The *Central Forest Winter Severity Index* for winter 2000-01 was 142.

2000-01 Predator and Prey Population Estimates:
The post-season deer herd was estimated at 450 deer (37 deer/mi^2) in Sandhill. Beaver reached a 21 - year low in 2001 with only 3 active colonies counted. Four to six coyotes were estimated to use portions of Sandhill during winter 2000-01. Only a single adult male wolf (named “Twisted Knee”) was found within Sandhill. This wolf has been present on Sandhill since 1995 and is estimated to be 7 years old.

***Trailing Data*:**
Table 3 yields comparative data from 1996 through 2001. Fourteen students from 7 school districts participated in the 28-day study. The total miles walked and driven, and the average daily miles walked and driven was lower than the 6-year average of 182.5 and 6.8 miles, respectively (Table 3). This was primarily caused by the low number of students participating in the program this year.

Table 3. Effort in searching for wolf sign, 1996-2001.

		Miles (km) traveled by Students					
Year	**# Days**	**Total Walked**	**Total Driven**	**0 Walked Daily**	**0 Driven Daily**	**Walked & Total**	**Driven 0 Daily**
1996	25	251.8 (402.7)	0	10.1* (16.1)	0	251.8 (402.7)	10.1* (16.1)
1997	35	202.4 (323.8)	63.7 (101.9)	5.8 (9.2)	6.4 (10.1)	266.1 (425.7)	7.6 (12.2)
1998	23	90.4 (144.7)	99.0 (158.4)	3.9 (6.2)	4.4 (6.9)	189.5 (303.0)	8.2 (13.2)
1999	19	52.8 (84.6)	15.75 (25.2)	2.8 (4.5)	15.75 (25.2)	68.6 (109.75)	3.6 (5.8)
2000	30	166.35 (266.16)	42.8 (68.5)	5.5 (9.5)	8.6 (13.8)	209.2 (336.6)	6.9 (10.2)
2001	28	63.4 (102.01)	47.8 (76.8)	3.5 (5.6)	5.9 (9.6)	111.2 (178.9)	3.9 (6.3)

*This data represents 2, 2-person crews daily. Therefore, each 2-person crew averaged 5.0 mi/day.

Wolf Tracking Data:
Tracking data on wolf trails is presented in Table 4. Daily wolf trail encounter rates have varied (range 37 to 76 percent); with most years falling in the area of 50-60 percent. The total miles tracked this winter (31.8) is slightly higher than the 6-year average of 28.7 miles. Two deer kills were found in 31.8 miles of tracking for an average of 16 mi (25.4 km) between kills, compared to the 6-year average of 9.7 miles (range 4.7 to 28.8 miles).

Scats: Five winter wolf scats contained 100 percent deer. Seven wolf scats collected during the snow-free season contained 57 percent deer; 14 percent lagomorph; 14 percent procyonid and 14 percent unknown mammal remains remains. One winter coyote scat contained 100 percent lagomorph remains.

Kill Statistics: Remains of four predator-killed deer were located in winter 2001 (Tables 5 and 6).

Table 4. Wolf tracking data, 1996-2001.

Year	# Days Trailed	Daily Encounter Rate (%)	Total Miles (km) Tracked	0 Miles (km) Tracked/Day	Longest Daily Session	# Deer Kills Found	Miles/Kill (km/kill)
1996	19	76	28.8 (45.2)	1.5 (2.3)	4.6 (7.4)	1	28.8 (46.0)
1997	23	66	44.2 (70.7)	2.3 (3.7)	5.2 (8.3)	7	6.3 (10.1)
1998	14	61	26.3 (42.1)	1.8 (2.9)	5.2 (8.3)	4	6.6 (10.6)
1999	19	37	9.4 (15)	0.5 (0.8)	1.5 (2.4)	2	4.7 (7.5)
2000	15	50	31.75 (51)	2.2 (3.4)	5 (8)	2	15.9 (25.4)
2001	15	54	31.8 (51.2)	2.6 (4.3)	5 (8)	2	15.9 (25.6)

Table 5. Cause of death of deer, by month, discovered January - March, 2001.

Mortality Type	January	February	March
Snow depth (in)	11	10.72	8.8
Wolf	0	2	0
Coyote	1	1	3
Starvation	0	0	8

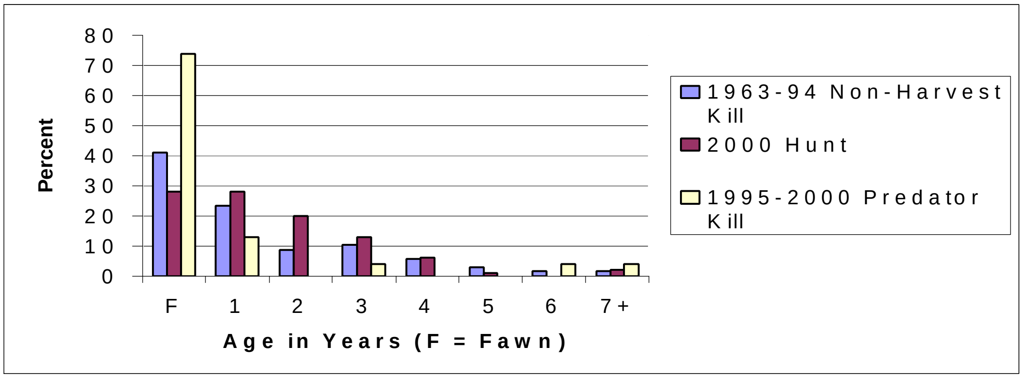
Table 6. Age, sex and condition of predator-fed deer located in 2001.

Map Loc	Date of Kill	Cause of Death	Sex	Age	Percent Consumed	Marrow Condition	Scavenged?
1	1-22	Unretrieved Hunter	M	1.5		red	By wolf
2	1-22	Coyote	M	F	25	red	Crows
3	2-3	Wolf	M	F	85% by wolf	Pink	5% by birds
4	2-13	Wolf	U[1]	F	75% by wolf	Pink	25% by coyotes & blue jays
5	2-21	Coyote	U	F	50% by coyotes	Pink	
6	3-19	Coyote?	F	F	25	Red	Possibly starved & scavenged
7	3-22	Starve	U	F	60	Pink	Possibly wolf kill

[1]unknown

Age Selection: Twenty-three known-age predator kills since 1995 are compared to the fall 2000 hunter-harvested deer, and non-harvest kills discovered in Sandhill between 1963 and 1994 in Figure 1. The age structure of non-harvested deer is assumed to most closely represent the actual age structure of the herd. Predators and hunters select different age groups of deer: predators selected primarily *young and some old* and hunters selected *prime-aged* (ages 1-4 years) deer relative to their occurrence in the herd.

Figure 1. Differences in age selection of deer in Sandhill Wildlife Area.



Kill and Utilization Rates, and Condition of Dead Deer: The 2000-2001 winter was characterized by modest snow depths, fairly mild temperatures, but a prolonged period of snow on the ground (viz: continuous snow cover in 2000-01 [134 days] was twice as long as the previous 2 winters [73 and 71 days respectively]). The observed utilization rate was 100 percent on 2 wolf-killed deer and 58 percent on 7 deer fed on by coyotes and/or the wolf (Table 6). Bone marrow condition was poor (66 percent pink: 34 percent red) on 6 of these deer. Six radio-collared deer died of starvation between 8 February and 23 March: one (17 percent) had pink bone marrow and the remainder red (63 percent). The poorer bone marrow condition suggests deer were nutritionally stressed this winter.

Deer Telemetry:
Capture Efforts, 2001: Table 7 yields data on trapnights (TN) during the study. Twenty-three deer were captured 53 times in 66 TN, for a success of 1 deer / 2.8 TN. Of these, twelve were radioed, and four radioed deer captured in previous years were monitored for portions of this winter study. Total trapnight effort varied from 32 in 1997, 44 in 1998, 38 in 1999, 18 in 2000 and 66 in 2001. Trapnights/capture ranged from 0.125 in 1997, 0.113 in 1998, 0.23 in 1999, 0.61 in 2000, and 0.35 in 2001.

Table 7. Deer capture success, Sandhill Wildlife Area, Winter 2001

Month	Trapnights	Captures	Recaptures	Snapped Traps
January	22	15	5	2
February	28	27	14	0
March	16	1	10	0
Totals	66	43	29	2

Productivity Trends: Summer 2000 deer observations reflected a fawn/ doe ratio of 0.92, up significantly from 0.47 in 1999, and 0.72 in summer 1998. Three of 6 radioed does produced 5 fawns for a net reproductive rate of 0.83 fawns per doe.

Survivorship Trends: Since this program began in January 1997, 7043 deer-days (19.3 deer-years) of telemetry survivorship data have been accumulated on individual deer. Survivorship was calculated at 13 percent for bucks, 44 percent for does, and 17 percent for fawns. This is probably not representative of “average” survival rates because of the inordinately high starvation deaths that occurred this past winter.

This is the second winter since this study began (1995-96) that deer succumbed to starvation. Table 8 reveals that young-aged deer (fawns and 1-year olds) and older deer (4+ years) were most susceptible to starvation, based on the fate of 16 radioed deer that entered the winter. One deer, buck 273, survived the previous severe winter (1996-97) as a yearling, and managed to elude hunters over the next several years. He was found dead of starvation in late March, aged 5.75 years.

Table 8. Age-related impacts of winter mortality on a pool of 16 radioed deer entering winter 2000-01.

➢ Age	Fawn	1	2	3	4	5	6
# Radioed Deer	**5**	**4**	**2**	**2**	**1**	**1**	**1**
# Starved	**2**	**2**	**0**	**0**	**1**	**1**	**1**
% Survival	**60**	**50**	**100**	**100**	**0**	**0**	**0**

Home Range Size: The size of 3 adult does’ home ranges ranged from 148 to 220 acres, and averaged 190.7 acres. Three buck home ranges ranged from 254 to 515 acres and averaged 360 acres. These radioed deer were located in the southeastern-most square mile of Sandhill (Map 2), with the exception of doe 96, who suddenly moved to dense conifer cover in northeast Sandhill when snows deepened, apparently vacating her home range of 2 years. She succumbed to starvation in mid March one mile southwest of her former home range. She was carrying one buck fetus at the time of her death.

Impact of Wolf Predation on Sandhill Deer Herd

Consumption Rate of Wolf: Based on the known number and ages of kills and scavenging of prey remains located in 2001, a consumption rate of 7 kg of meat/day was calculated for the Sandhill wolf during the 28-day study period (Table 9). This is higher than previous winter rates recorded in this study. Table 9 also compares the consumption rate in the present study with a pack of eight wolves studied in Ontario by Kolenosky (1972). Consumption rates in the present study are higher than reported for a pack of 8 wolves studied by Kolenosky (1972) in Ontario, and by Mech (1977) in northeastern Minnesota (Table 9).

Fall Scavenging Potential - Harvested Deer Gut Piles and Unretrieved Kills: Hunters harvested 79 deer in November 2000. This represents 929 kg of gut piles (66.4 kg or 145 pounds per square mile); potential food for wolves and coyotes. In addition, 3 unretrieved hunter-killed deer carcasses were discovered for an additional 121 kg of potential food for canids. One of these deer was partially consumed by a flock of turkey.

Table 9. Consumption rate of wolves in Sandhill and in Ontario (Kolenosky 1972).

Location	Number of Wolves	Year	Deer Density deer/mi^2 (deer/km^2)	Ave. mi (km) per kill	Ave. days per kill	Days/Kill/Wolf	Food/Wolf/Day (kg)
Ontario	**8**	**1968-69**	**8.6 (5.4)**	**8.8 (14.2)**	**2.2**	**17.7**	**2.8**
Sandhill	**1**	**1996-97**	**24.7 (15.4)**	**6.3 (10.1)**	**4.5**	**4.5**	**4.4**
Sandhill	**3**	**1997-98**	**25.0 (15.6)**	**6.6 (10.5)**	**3.5**	**10.5**	**4.2**
Sandhill	**1**	**1998-99**	**25.0 (15.6)**	**13.0 (21)**	**7.0**	**7.0**	**2.8**
Sandhill	**1**	**1999-2000**	**29.0 (18.1)**	**N/A**	**7.5**	**7.5**	**5.0**
Sandhill	**1**	**2000-01**	**32.1 (20.1)**	**15.9 (25)**	**7.5**	**7.5**	**7.1**

Table 10 breaks down the calculation of deer taken on Sandhill by season. In the present biological year (1 June 2000 to 31 May 2001) the wolf consumed the equivalent of 27 deer. Over the 6-year study, this figure has ranged from 14 to 37 deer/wolf/year.

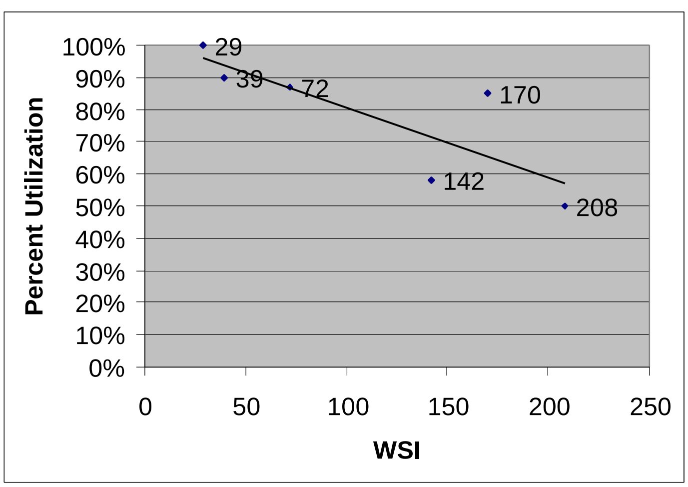
Adjusted Impact of Wolf Presence on Deer Herd: Assuming the amount of food the wolf scavenged (70 kg, or the equivalent of 1.3 deer at 54 kg each) compensated for a live deer he would have "removed" from the herd, the adjusted take in 2000-01 would have been 26 deer. This does not include any compensation for scavenging on gut piles.

Discussion

This was the second winter in this six-year study that the deer herd experienced winter-related stress. All wolf sign was attributable to the lone male wolf who entered the facility in May 1995.

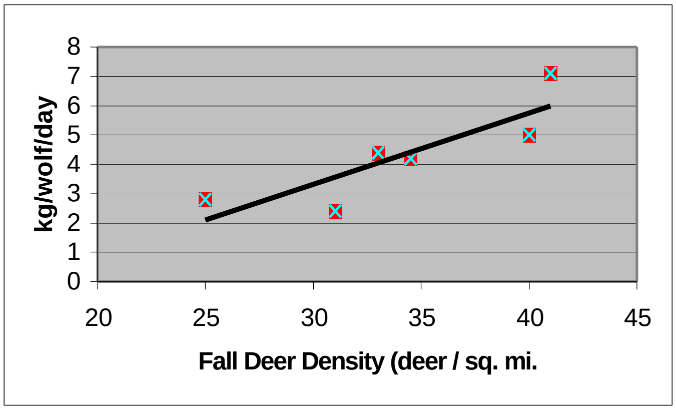
Percent utilization of deer carcasses by the wolf and by coyotes appears to be related to winter severity (Figure 2).

Figure 2. Percent utilization of deer carcasses by coyotes and a wolf on Sandhill compared to WSI, 1996-2001.



Daily consumption rates by the wolf does not appear to be related to WSI. It does appear to be related to autumn deer densities (Figure 3).

Figure 3. Daily winter consumption rates of a wolf in relation to autumn deer densities, 1996-2001.



This single wolf consumed an estimated 26 deer on Sandhill in 2000-01. The average number of deer harvested annually by hunters is 77 deer (Table 11). We believe the presence of wolves on Sandhill represents an *additive* source of mortality for deer. However, humans normally harvest fewer deer annually from the Sandhill herd than are recruited through reproduction (recruitment is (350 X 1.3) – 350 = 100 fawns). The combined effect of a human harvest averaging 77/year and wolf predation averaging 20/year has not prevented an increase in the mid-winter deer population from 351 deer in 1999-2000 to 450 deer in 2000-2001. Additional deer may need to be harvested to reduce the likelihood of starvation in future winters.

Table 10. Calculated annual "take" of deer by wolves on Sandhill, March, 2000 – February 2001.

Period	Kg/Wolf/Day	# Days	% Deer in Scats	# Wolves	Total Wt (kg) Consumed	Total Weight)0 Deer Wt	Total Deer
June – Aug 2000	5	92	60	1	276	54	5.1
Sep – Nov	5	92	60	1	276	54	5.1
Dec – Feb	7.1	91	100	1	646	54	11.9
Mar – May 2001	5	90	60	1	276	54	5.1
Year 2000 – 01 Sum				1	1474.1		27.3

Table 11. Deer harvest and population trends, Sandhill Wildlife Area, 1991- 2000.

Biological Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	Ave
Hunter Harvest	55	146	49	56	63	54	76	62	133	79	77.3
Wolf					14	20	37	23	20	27	20.2
Total	55	146	49	56	77	74	113	85	153	106	91.4
Deer Trail Survey[1]	351	296	409	399	382	402	422	306	490	504	
Helicopter Census[2]	431		191			346			351	450	

[1]fall survey before hunting season [2]winter count following hunting season

We recommend the following:
(1) Continue to monitor canid predation and assess consumption rates of wolves and coyotes on Sandhill,
(2) monitor radioed deer to determine *annual* home range sizes, and maintain contact with an average of 6 adult deer per year in the SE study area,
(3) determine fawn recruitment of radioed does in Sandhill,
(4) place ear-tag transmitters on 2-4 fawns in winter 2001-02, and
(5) obtain at least 25 radio locations per year to assess deer home range sizes.

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Literature Cited

Anonymous. No date. Aging a deer. Information leaflet. New York State Conservationist.

Boehm, Fred. 1997. The lone male wolf of the Sandhill Wildlife Area. International Wolf. Vol 7(3): 7-9.

Fuller, T. 1991. Effect of snow depth on wolf activity and prey selection in north central Minnesota.Can. Journ. Zool. 69: 283-287.

Grund, M. D. 1998. Movement patterns and habitat use of an urban white-tailed deer population in Bloomington, Minnesota. Masters Thesis. University of Missouri - Columbia. 63 pp.

Kolenosky, G. 1972. Wolf predation on wintering deer ineast-central Ontario. Journ. Wildl. Manage. 36: 357-369.

Marchinton, R. L., and D. H. Hirth. 1984 . Chapter 6: Behavior pp. 129-168 *in* Lowell K. Halls (ed) White-tailed deer ecology and management. Wildlife Management Institute. Stackpole Books.

McRae, B. 1994. Wolves ate my whitetail! Hunting: 41-42, 124.

Mech, L. D. 1977. Population trend and winter deer consumption in a Minnesota wolf pack.pp. 55-83 *in* Proceedings of the 1975 predator symposium, Missoula, Montana, June 16-19, 1975.R. L. Phillips and C. Jonkel, (Eds.). Montana Forest and Conserv. Exp. Sta. Univ. Montana, Missoula.

Mech, L. D. 1983. Handbook of animal radio-tracking. Univ. Minn. Press. 107 pp.

Mech, L. D. and L.D. Frenzel. 1971. An analysis of the age, sex, and condition of deer killed by wolves in northeastern Minnesota. pp. 35-51 *in* Mech, L. D. and L.D. Frenzel (Eds.). Ecological studies of the timber wolf in northeastern Minnesota. N. Cent. Forest Exp. Sta., USDA Forest Serv. Res. Pap. NC-52. St. Paul, MN.

Mech, L. D. And G. DelGiudice. 1985. Limitations of the marrow-fat technique as an indicator of body condition. Wildl. Soc. Bull. 13: 204-206.

Nelson, M. 1981. Home range location of white-tailed deer.U.S.D.A. Forest Serv. Research Pap. NC-173.

Paquette, P. 1992. Prey use strategies of sympatric wolves and coyotes in Riding Mountain National Park, Manitoba. Journ. Mammal. 73:337-343.

Pryse, J. 1997. Protection for wolves topic at DNR hearing. Marshfield News Herald. April 15.

Thiel, Richard P. 1993. The timber wolf in Wisconsin: the death and life of a majestic predator. University of Wisconsin Press. 253 pp.

Thiel, Richard P. 2000. Successful release of a wild wolf, *Canis lupus*, following treatment of a leg injury. Canadian Field-Naturalist. 114: 317-319.

Thompson, D. Q. 1952. Travel, range, and food habits of timber wolves in Wisconsin. Journ. Mammal. 33:429-442.

Weaver, J. And S. Fritts. 1979. Comparison of coyote and wolf scat diameters. Journ. Wildl. Mange. 43: 786-788.

Wisconsin Department of Natural Resources. 1997. Kill and consumptive rates of a lone, male timber wolf, Sandhill Wildlife Area - 1997. Unpubl. Rept. Sandhill Outdoor Skills Center. 6 pp.